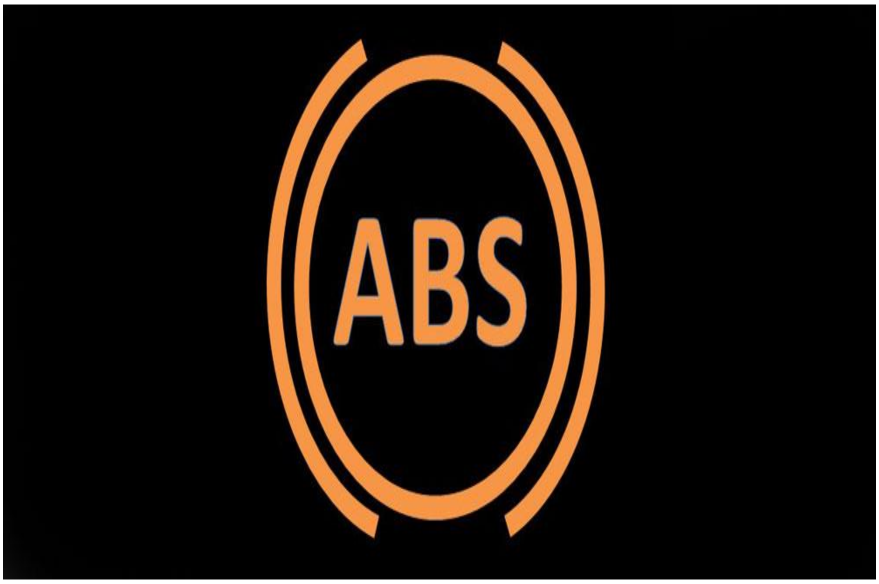
Modeling of Antilock Braking System



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• Introduction

An anti-lock braking system (ABS) is a safety anti-skid braking system used on aircraft and on land vehicles, such as cars, motorcycles, trucks, and buses. ABS operates by preventing the wheels from locking up during braking, thereby maintaining tractive contact with the road surface and allowing the driver to maintain more control over the vehicle.

ABS is an automated system that uses the principles of threshold braking and cadence braking, techniques which were once practiced by skillful drivers before ABS was widespread. ABS operates at a much faster rate and more effectively than most drivers could manage. Although ABS generally offers improved vehicle control and decreases stopping distances on dry and some slippery surfaces, on loose gravel or snow-covered surfaces ABS may significantly increase braking distance, while still improving steering control. Since ABS was introduced in production vehicles, such systems have become increasingly sophisticated and effective. Modern versions may not only prevent wheel lock under braking, but may also alter the front-to-rear brake bias. This latter function, depending on its specific capabilities and implementation, is known variously as electronic brakeforce distribution, traction control system, emergency brake assist, or electronic stability control (ESC).

• Background

This model of Anti-Lock Braking System (ABS) simulates the dynamic behaviour of vehicle under hard breaking conditions.

The wheel rotates with an initial angular speed that corresponds to the vehicle speed before the brakes are applied. We used separate integrators to compute wheel angular speed and vehicle speed. We use two speeds to calculate slip, which is determined by Equation 1. Note that we introduce vehicle speed expressed as an angular velocity.

$$\omega_v = \frac{V}{R} \text{ (equals the wheel angular speed if there is no slip)}$$

Equation 1:

$$\omega_v = \frac{V_v}{R_r}$$

$$slip = 1 - \frac{\omega_w}{\omega_v}$$

$\omega_v =$ vehicle speed divided by wheel radius

$V_v =$ vehicle linear velocity

$R_r =$ wheel radius

$\omega_w =$ wheel angular velocity

From these expressions, we see that slip is zero when wheel speed and vehicle speed are equal, and slip equals one when the wheel is locked. A desirable slip value is 0.2, which means that the number of wheel revolutions equals 0.8 times the number of revolutions under non-braking conditions with the same vehicle velocity. This maximizes the adhesion between the tire and road and minimizes the stopping distance with the available friction.

• Modeling

The friction coefficient between the tire and the road surface, mu, is an empirical function of slip, known as the mu-slip curve. We created mu-slip curves by passing MATLAB variables into the block diagram using a Simulink lookup table. The model multiplies the friction coefficient, mu, by the weight on the wheel, W, to yield the frictional force, Ff, acting on the circumference of the tire. Ff is divided by the vehicle mass to produce the vehicle deceleration, which the model integrates to obtain vehicle velocity.

In this model, we used a state flow controller that used to yield +1/-1 based on the feedback error obtained (error between actual slip and desired slip).

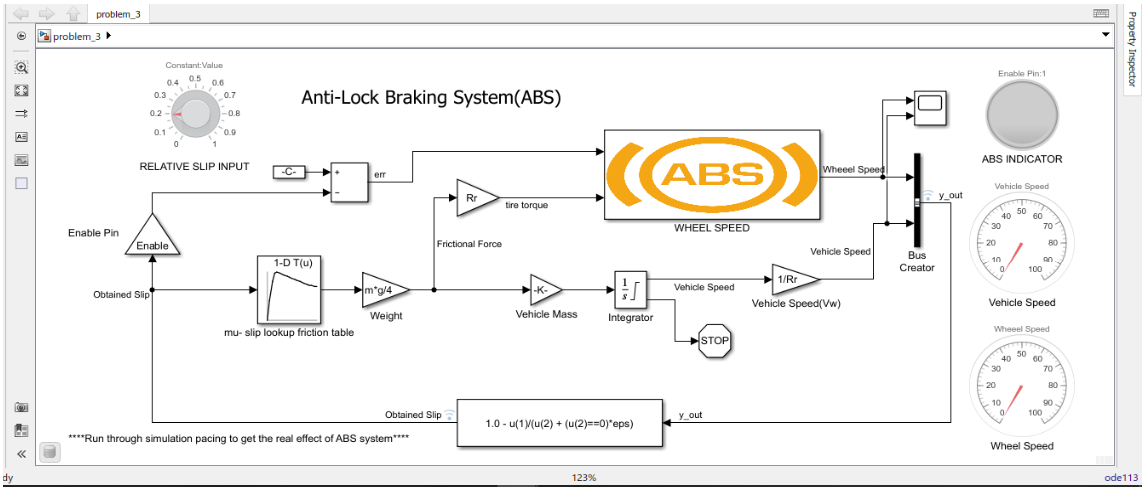

Figure 1

To control the rate of change of brake pressure, the model subtracts actual slip from the desired slip and feeds this signal into a bang-bang control (+1 or -1, depending on the sign of the error). This on/off rate passes through a first-order lag that represents the delay associated with the hydraulic lines of the brake system. The model then integrates the filtered rate to yield the actual brake pressure. The resulting signal, multiplied by the piston area and radius with respect to the wheel (Kf), is the brake torque applied to the wheel.

The model multiplies the frictional force on the wheel by the wheel radius (Rr) to give the accelerating torque of the road surface on the wheel. The brake torque is subtracted to give the net torque on the wheel. Dividing the net torque by the wheel rotational inertia, I, yields the wheel acceleration, which is then integrated to provide wheel velocity. In order to keep the wheel speed and vehicle speed positive, limited integrators are used in this model.

• Running the Simulations & Selection of Solvers

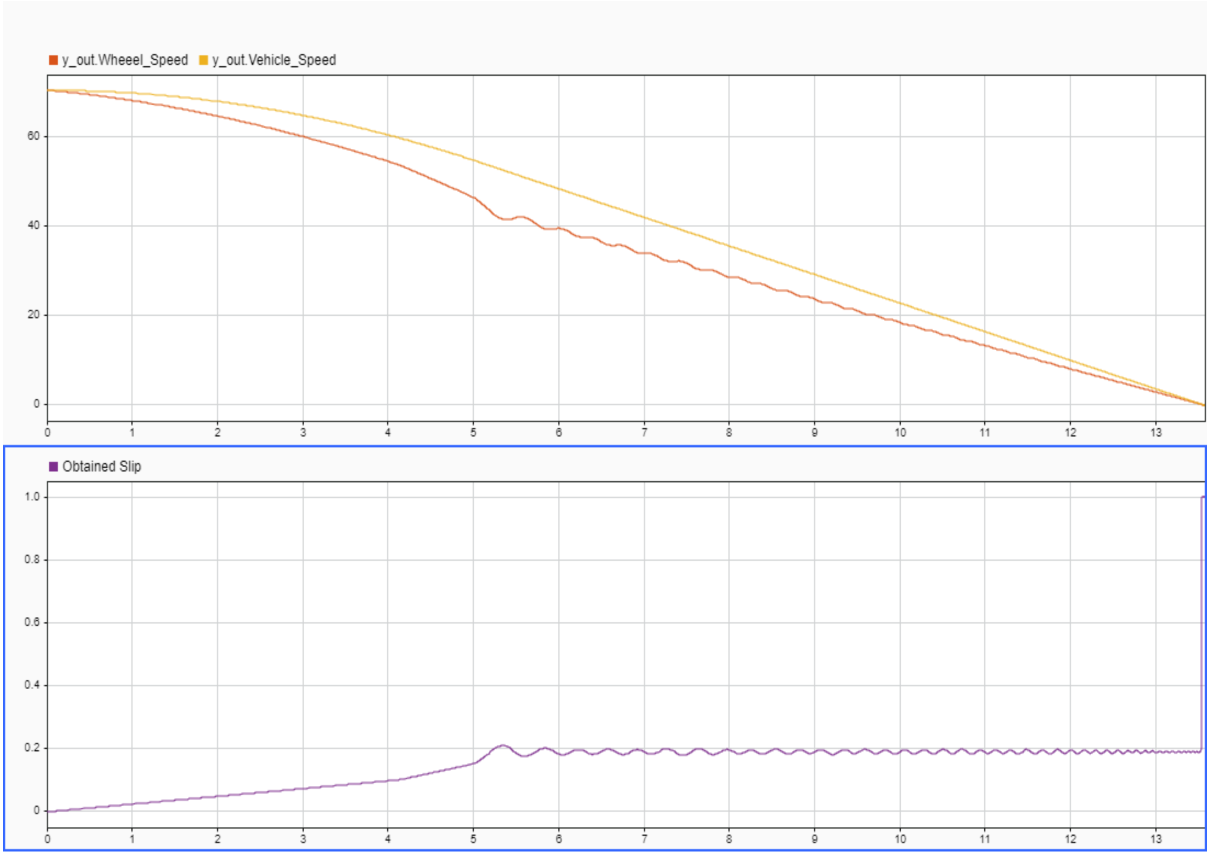

Figure 2

- In the model I have used Pre-Load in **Callbacks** section of the Model Explorer to preload the Vars.m.
- In the Model I have **Logged** the signals Wheel speed and Vehicle speed to check the accuracy of the ABS System. The obtained slip value Is also logged to check its accuracy.
- From the figure 2 we can observe that since we have set the relative slip value close to 0.2 the obtained wheel speed and vehicle speed are close enough and the wheel speed is locking up (wheel speed =0).
- The Relation between mu- slip which was required the calculate the Frictional force was obtained by **1-D Lookup Table.**
- The **Signal Builder** could be used as an alternative to the constant block to provide input to the required slip, we used constant block because we needed the working of ABS system for a fixed slip value.

Selection of the Required Solver:

- During the First try of the model I have used ODE 45 as the default variable step solver but it had a medium accuracy and it took a execution time of 13.623 seconds.
- During the second try I tried a basic fixed step solver with step size of 0.1 using Runge-Kutta method but it led to low accuracy.
- The accurate result and negotiable execution time were obtained in variable step ODE113 solver (Adams) which resulted in exaction time of 13.575 seconds.

Working the Brakes without ABS

- When we disable the Enable pin =0 in Gain block then the feedback is disconnected and ABS is not active.
- The figure 3 below shows the obtained result in such condition.

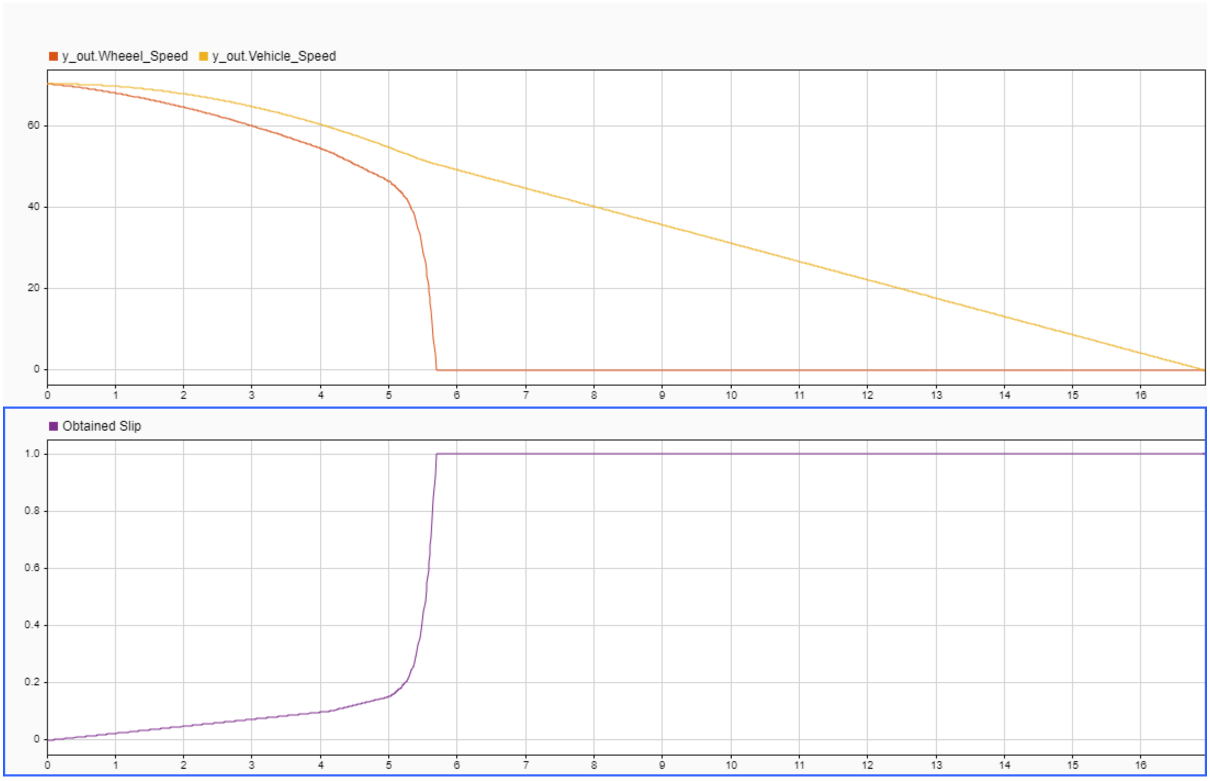

Figure 3

- In the above state when ABS in not active the we can see that Wheel speed reaches to 0 even though the vehicle is in motion this results to Slip of the vehicle and we get Obtained slip value as 1.